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Dolomite Cement Stratigraphy of the Reelfoot Rift and the Relationship of These Cements to Dolomite Cements Found in Southeast Missouri

Timothy James Keller

DOLOMITE CEMENT STRATIGRAPHY OF THE REELFOOT RIFT AND THE RELATIONSHIP OF THESE CEMENTS TO DOLOMITE CEMENTS FOUND IN SOUTHEAST MISSOURI

Timothy James Keller, Department of Geology and Geophysics

ABSTRACT:

The formation of the southeast Missouri Mississippi Valley-type Pb, Zn, Cu ore districts have been a subject of controversy. Using petrology and geochemistry, earlier studies have attempted to reveal fluid flow, composition, and origin of the ore forming fluids. In this study, the potential role of the Reelfoot rift (New Madrid seismic zone) as a source and/or conduit for ore forming fluids is addressed. By observing cuttings and cores from four oil test wells within the Reelfoot rift using cathodluminescence, four cement types were described: 1) A multiple generation cement type similar to that observed associated with mineralization in southeastern Missouri (type I). 2) A simple two generation cement type (type II). 3) A layered non-luminescent to dully luminescent cement type (type III). 4) A brightly luminescent cement type (type IV). Each cement type was observed at different stratigraphic horizons within the study area. The paragenetic sequence of the observed cements indicates that type III was deposited first followed by type IV and finally type II. Since type I cement was not observed in the same samples as the other cements, its paragenetic relationship to the other cements cannot be determined. The undiscernible paragenetic sequence coupled with the variable stratigraphic occurrence of the cement types makes it difficult to determine the role of the Reelfoot rift as an absolute source and /or conduit for mineralizing fluids without further geochemical investigations.

INTRODUCTION:

Studies of dolomite cement stratigraphy in southeastern Missouri have become increasingly important to understanding regional fluid flow during mineralization. These studies along with fluid inclusions and Strontium, Carbon, and Oxygen isotopes studies are utilized to determine the origin, composition, flow direction and possible interaction of basinal fluids. In this study, the abundance and types of dolomite cements in the Reelfoot rift and the similarities between these cements and the dolomite cements found in Mississippi Valley type (MVT) ore districts are addressed. The type and estimated paragenesis of rift related dolomite cements are used to determine the potential role of the Reelfoot rift as a source and/or conduit of mineralizing fluids in the Viburnum trend ore district.

GEOLOGIC SETTING:

The Reelfoot rift is an alaucogen located on the southern edge of the North American craton. The rift extends northeasterly from a junction with the eastern extension of the Ouachita orogen in East Central Arkansas. The southern portion of the Reelfoot rift links the Arkoma and Black Warrior basins. The northern end of the rift forms a structurally complex junction with the Rough Creek Graben, the Ste. Genevieve fault, the southern Illinois district, the fluorospar fault complex, and the deepest portion of the Illinois basin. To the east of the rift is the Ozark dome while to the West of the rift is the Nashville dome (Howe and Thompson 1984) (Fig. 1)

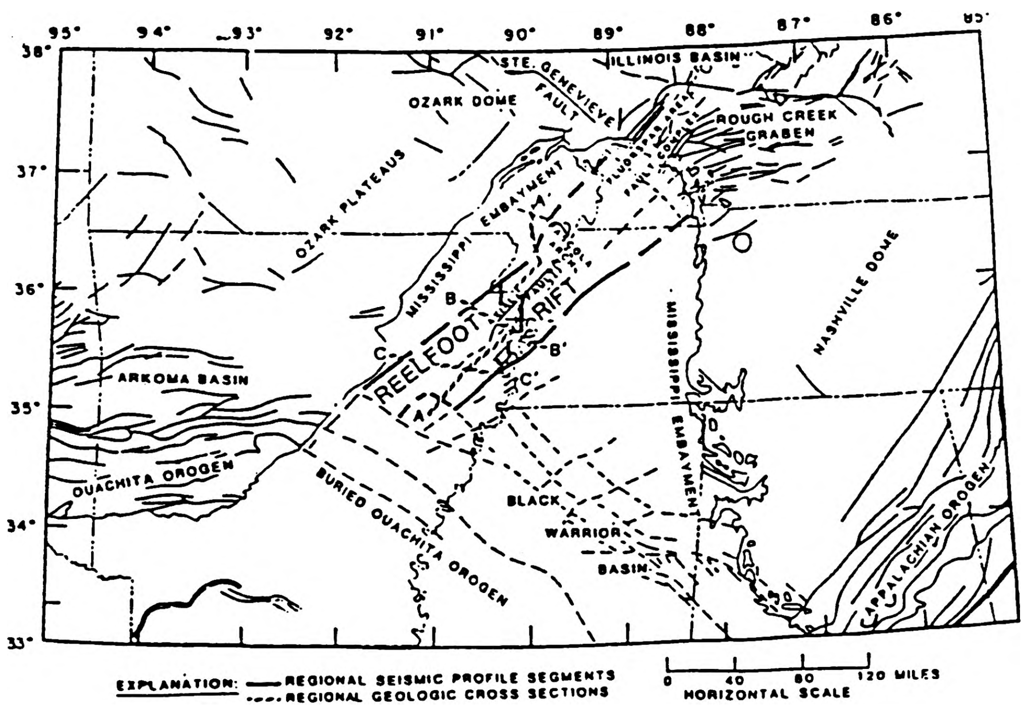

Figure 1. **Regional Setting of the Apparent Reelfoot Rift Boundaries Relative to Major Faults, Highlands, and Basins (After Howe and Thompson 1984).**

Subsidence of the Reelfoot rift began in the Precambrian between 1.3 and 1.1 b.y. B.P. During this time, the area comprising the present Mississippi embayment and the Illinois basin experienced epeirogenic uplift (Burke and Dewey 1973). This extensive uplift produced an axial rift or graben system (Fig. 2A) which has remained periodically active since the Precambrian time (Caplan 1954; Phelan 1969). Erosion leveled the uplifted surface of the rift at the end of the Precambrian time (Ham and Wilson 1967). The early Paleozoic time (Fig. 2B) was marked by subsidence of the rift (Ervin and McGinnis 1975). From the end of the early Paleozoic time to the end of the Paleozoic Era (Fig. 2C), the rift underwent a widespread, intermittent, gradual uplift (Caplan 1951; Ham and Wilson 1967; Tikrity 1968). The early and middle

Mesozoic Era (Fig. 2C) was a time of emergence an relative quiescence (Moore 1970). By early to late Cretaceous time (Fig. 2D), formation of the modern embayment began by "reactivation" of the ancient rift (Caplan 1954). This subsidence (Fig. 2E) has continued to the present time as evidenced by periodic, historic, seismic activity in that region (McGinnis 1963, 1970).

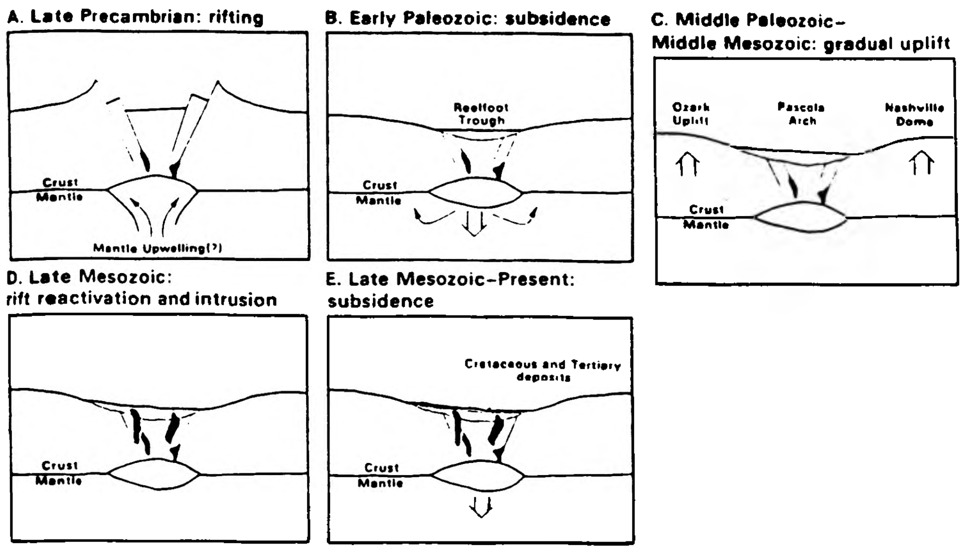

Figure 2. Cross Sections of the Reelfoot Rift Through Time (After Ervin and McGinnis 1975). A) Late Precambrian Rifting. B) Early Paleozoic Subsidence. C) Middle Paleozoic - Middle Mesozoic Gradual Uplift. D) Late Mesozoic Rift Reactivation and Intrusion. E) Late Mesozoic - Present Subsidence

A petrographic study of the Reelfoot rift by Tobin (1990) addressed the paleotemperatures and burial history of Cambrian carbonate rocks. The paleotemperatures observed in these rocks varies from 25 ºC to a maximum of 235 ºC at the Paleozoic unconformity. After the unconformity, the paleotemperature decreased to the present value of 74 ºC. The observed burial history of these rocks includes an initial burial in the Cambrian and two periods of uplift: One in the Lower Cretaceous. The other from the Tertiary to the present. A later study of the upper Cambrian and lower Ordovician sedimentary rocks of the Reelfoot rift by Shelton et al. (in review) focused on fluid-rock interactions of the hydrothermal dolomite. This study revealed a simple two zone CL cement associated with a very hot (250 ºC), primitive basinal fluid.

Cathodluminescence (CL) studies of dolomite cements associated with mineralization in the Viburnum trend and elsewhere in southern Missouri have revealed four distinct zones of dolomite cements (Fig. 3) (Gregg 1985; Voss and Hagni 1985; Rowan 1986; Voss et al. 1989): Zone 1 is a pre-ore cement which closely resembles the host replacement dolomite. Zone 2 shows dully luminescent banding to non-luminescent banding. Zone 3 is composed of many luminescent bands while zone 4 is a non-luminescent band (Voss et al. 1989).

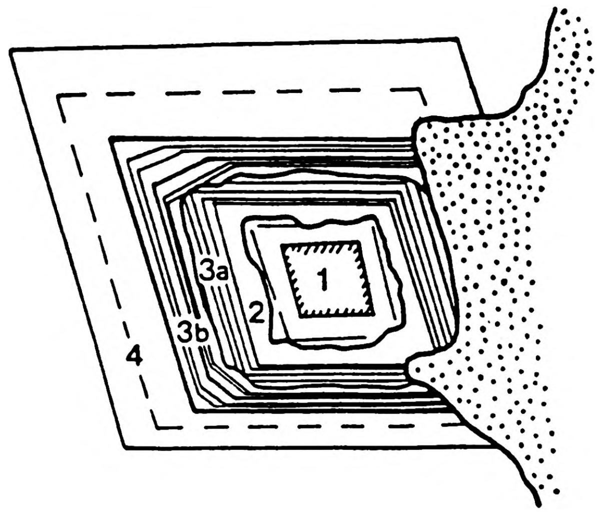

Figure 3. **Illustration of Cathodluminescent Zonation Found in Dolomite Cements of the Southeastern Missouri District (After Voss et al. 1989).**

The purpose of this study is to determine the relationship of CL cement stratigraphy of dolomite cements in the Reelfoot rift with that of epigenetic gangue dolomite cements associated with MVT mineralization in the Ozark region of southeastern Missouri. This will provide evidence as to the importance of the rift as a source and/or conduit for mineralizing fluids in that region.

PROCEDURE:

Cuttings and core samples were obtained from four oil test wells within the Reelfoot rift (Fig. 4). Samples of cuttings were selected for petrographic study on the basis of identification of important features noted on the well logs such as: The different lithologies, porosity, and sulfide mineralization. Cutting and core samples were mounted as polished thin sections. Samples were described using a polarizing petrographic microscope and a Technosyn cold cathode CL apparatus. The CL apparatus was operated under optimum conditions of 12 - 15 kilovolts at a gun current of 150 - 180 milliamperes, under a vacuum of .04 - .07 torr.

RESULTS:

The lithology of the rocks in the core and cutting samples grade from platform carbonates in the Marr and Oliver wells, through platform margin carbonates in the Spence well, and finally to basinal shales, sands, and carbonates in the Strake well (Fig. 4). Much of the original limestone lithology has been destroyed due to extensive dolomitization.

Medium grained (10μm - 1200μm), nonplanar dolomite was interpreted to be epigenetic. Under CL, this epigenetic dolomite exhibits a dull red color to nonluminescent. Planar dolomites examined in this study are medium crystalline (75μm - 1500μm) and interpreted to be of early diagenetic origin. The dolomite cements discussed below were observed associated only with nonplanar dolomite.

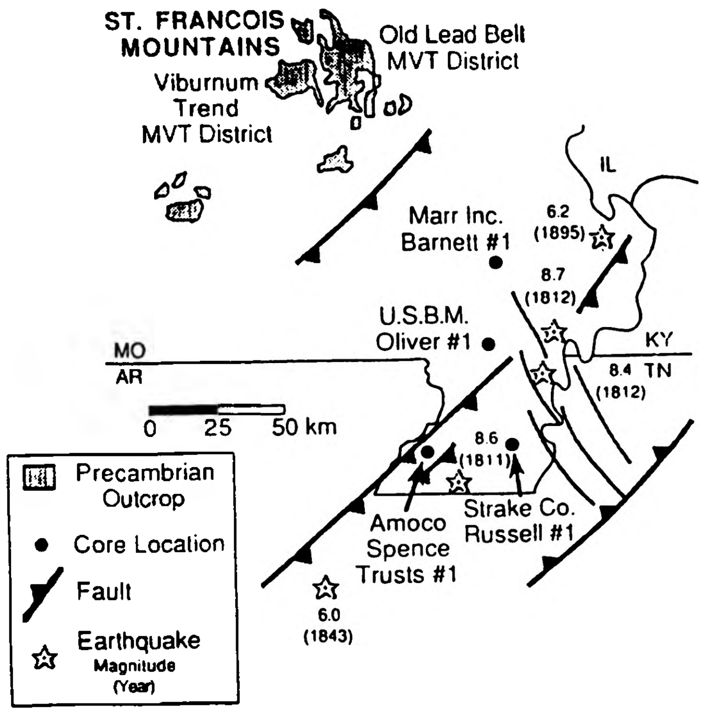

Figure 4. Location of the Study Area Relative to the St. Francois Mountains, Major Tectonic Features, and Other Mississippi Valley-Type Mineral Districts (From Shelton et al. in review).

Disseminated sulfides are quite common in the wells studied. Pyrite, the most common of the sulfides observed, can be found throughout most of the formations and in all of the wells investigated. In the Marr well, disseminated sphalerite occurs very deep (1,380 m) while disseminated chalcopyrite occurs from 682 m to 1,017 m. Both of these minerals are associated with nonplanar dolomite. In the Oliver well, disseminated sphalerite is present while disseminated chalcopyrite is not The sphalerite occurs at depths of 733 m to 1,118 m in nonplanar dolomite that is void of dolomite cements. At 733 m, disseminated sphalerite occurs on one grain of dolomite that contains dolomite cement. In the Spence well, massive sphalerite and pyrite commonly occur with dolomite cements. The Strake well, like the Oliver well, contains only disseminated Sphalerite. The sphalerite occurs at 1,061 m on non-planar dolomite which is free of dolomite cement.

Four categories of dolomite cements were observed using CL petrography: 1) A multiple generation cement similar to that observed associated with mineralization in southeastern Missouri (e.g. Voss el al. 1989). This type of cement consists of a dully luminescent cement followed by a multi-banded dolomite cement and then a non-luminescent cement zone (type I) (Fig. 5). 2) A simple two generation cement type consisting of a dark inner CL zone and a bright outer CL zone (type II) (Fig. 5). 3) A layered non-luminescent to dully luminescent cement type consisting of a non-luminescent inner zone of dolomite cement followed by a zone of slightly more luminescent cement than the host dolomite (type IIIa). Type IIIb cement consists of a zone of non-luminescent cement followed by a zone of slightly luminescent cement which covers type IIIa cements. 4) A brightly luminescent cement observed in fractures which postdates all other types of cements (type IV).

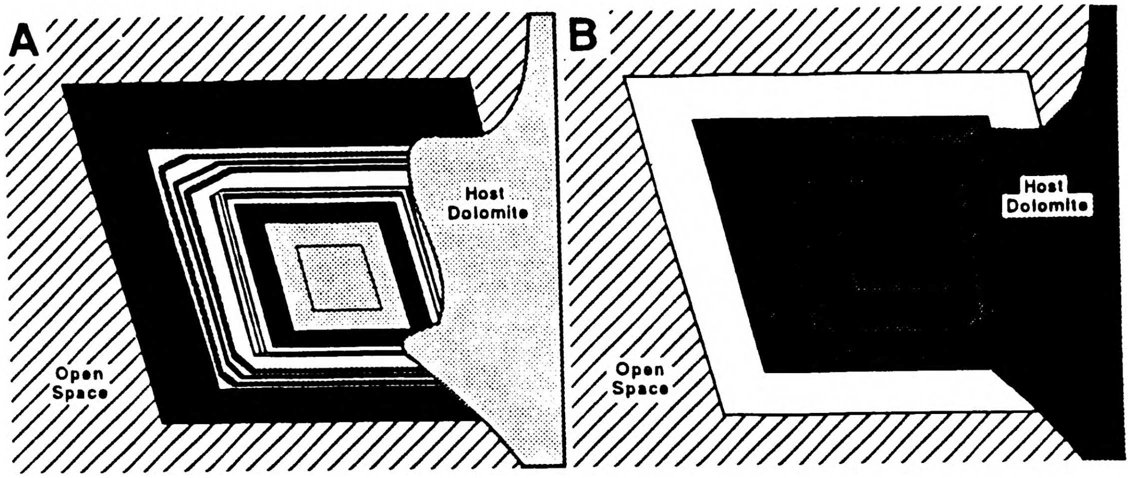

Figure 5. Dolomite cement stratigraphy types observed in the Reelfoot rift. A) Illustration of multi-zoned type I cements. B) Illustration of two generation type II cements.

Marr Number 1:

Dolomite cements in the Marr well were observed in the Roubidoux, Upper Gasconade, Lower Gasconade, Eminence, Potosi, Davis-Derby, and Bonneterre Formations. The first appearance of cements is at 424 m (Roubidoux Fm.) (Fig. 6). There, type IIIb cement is veined and covered by type IV cement. This sequence, in turn, is covered by a later calcite cement. Type II and type IIIa cements also are found at this stratigraphic level. At 501 m (Upper Gasconade Fm.), type IIIa and type IV cements occur (Fig. 6). From 530 m (Lower Gasconade Fm.) to 682 m (Eminence Fm.), type IIIa cement is prevalent (Fig. 6). At 818 m (Potosi Fm.), type IIIb and type IV cements appear (Fig. 6). The Davis-Derby Formation (1,017 m) contains type I cement while samples from a depth of 1,212 m (Bonneterre Fm.) contain type II cements (Fig. 6). Another sample from the Bonneterre Formation (1,380 m) contains only calcite cement veins cutting undolomitized limestone (Fig. 6).

Oliver U.S.B.M. Number 1:

The Oliver well records extensive dolomite cementation from a depth of 460 m to depths greater than 1,118 m. These cements span the Jefferson City, Roubidoux, Eminence, Potosi, Doe-Run, Davis, and Bonneterre Formations. From 460 m (Jefferson City Fm.) to 733 m (Eminence Fm.), type I dolomite cement is observed (Fig. 6). In one polished section at 733 m, type IIIa dolomite cements are covered by type II dolomite cements (Fig. 6). Type II dolomite cements appear at 770 m (Potosi Fm.) (Fig. 6). From 800 m (Potosi Fm.) to 936 m (Derby Fm.), type IIIb dolomite cement are found in the larger vugs and veins while type IIIa dolomite cements are observed in the smaller veins and vugs (Fig. 6). Samples from 895 m - 900 m and 936 m contain type IIIb dolomite cements which terminate in type II cements (Fig. 6).

Depth	Marr	Oliver	Spence	Strake
400 m				
	type IIIb, type IV*, calcite cement*			
	type II, type IIIa	type I		
500 m	type IIIa,type IV			
	type IIIa	type I		
600 m				
	type IIIa			
700 m				
		type I, type IIIa, type II*		type II
		type II		
800 m		type IIIa, type IIIb		
	type IIIb, type IV	type IIIa, type IIIb		type I
		type IIIa, type IIIb		
		type IIIa, type IIIb		
900 m		type IIIb, type II*;		
		type IIIb, type II*		type IIIa, type IV*
				calcite cement
1000 m				
	type I			
				type IIIa, type IV*
		type II, calcite cement, type IIIb*		
1100 m		type IIIa		
		type IIIb		
1200 m				
	type II			
1300 m				
	calcite cement			
1400 m			2,344 m and 2350 m	
			spence type cement	

Figure 6. Stratigraphic Occurrence of the Dolomite Cements in Each of the Wells Studied.
* cement type with this character indicates that it is paragenetically later than the cement type preceding it, i.e. type IIIa, type II* means that type II cement deposited on type IIIa cement.

A sample from 1,079 m (Bonneterre Fm.) contains type II dolomite cements (Fig. 6). Deeper in the Bonneterre Formation (1,093 m), calcite cements resembles the layering in type IIIb dolomite cements (Fig. 6). This calcite cement is then coated by type IIIb dolomite cements. At 1100 m (Bonneterre Fm.), type IIIa cements were observed (Fig. 6). The bottom of this well (1118 m) contains slightly darker red luminescent type IIIb dolomite cements (Fig. 6).

Spence Trust Number 1:

Dolomite cements from the Spence trust well were observed in cored intervals at a depth of 2,344 m and 2,358 m. They are uniform open-space filling cements which are similar to type II dolomite cements but differ in the first generation. The first generation of cement in the Spence trust well is non-luminescent while the first generation of type II cement observed elsewhere in the rift area is dully red luminescent possibly indicating a higher $FeCO_3$ content in the Spence cement.

Strake Number 1:

Although the Strake well also exhibits all four types of dolomite cements observed, the stratigraphic interval in which they occur is more restricted than in the other wells. Dolomite cements only occur in the Eminence, Potosi, Derby, and Bonneterre Formations. In the Eminence Formation at 707 m - 708 m, type II dolomite cements are evident (Fig. 6). Deeper in the well at 852 m - 855 m (Potosi Fm.), type I cement was observed within the intracrystalline porosity (Fig. 6). Since the small pore size limits the growth of the cement, the terminal dark layer typically is missing. At 910 m (Derby Fm.) and 1061 m (Bonneterre Fm.), type IIIa cements are coated by and associated with veins of type IV cements. At 924 m (Derby Fm.), a calcite cement occurs.

DISCUSSION:

Although the full paragenetic sequence could not be determined due to the non-association of type I cements with types II, type III, and type IV, a partial paragenetic sequence of cementation could be determined for each of the four wells. This paragenetic sequence includes: Type IV cement occurs paragenetically later than type II, type IIIa and type IIIb cements. Type II cement occurs later than type IIIa and IIIb dolomite cements. Calcite cement occurring later that the type IV dolomite cement. Correlating the paragenetic sequence of these wells gives a partial overall paragenetic sequence of type IIIa, followed by type IIIb, which then was followed by type II, type IV, and finally calcite cement.

Type I, type II, and type IV cements resemble the color and structure of CL cements previously studied either elsewhere in southern Missouri as is the case with type I or in the rift, as is the case with type II (e.g. Shelton et al. in review). Type III cements, on the other hand, do not resemble any cement type previously studied.

The first generation of cement found in the Spence well is much higher in $FeCO_3$ than the first generation of type II cement observed elsewhere. This difference could suggest that the first generation of the Spence trust well cements were formed by an isolated or different fluid than the first generation of other type II cements. The similarity in luminescence of the second generation cements in each well suggests formation by a similar fluid. Type IV cement resembles the second generation of both the Spence trust cement and type II cement observed elsewhere. Type IIIa and type IIIb dolomite cements are not similar to other dolomite cements in southeast Missouri or the rifted area. This indicates that type III dolomite cements were formed by a fluid different than the fluids related to the Southeast Missouri ore districts and those that precipitated type II cements. The relative composition of the cements observed were determined by their luminescence. The composition of cements present ranges from high mol% $FeCO_3$ (no luminescence) to very low mol% $FeCO_3$ (bright luminescence). Type I dolomite cement, overall, is relatively low in $FeCO_3$ with local bands ranging from high to relatively low $FeCO_3$ content. Type II dolomite cements have a first generation cement moderately high to very high in $FeCO_3$ and second generation cement very low in $FeCO_3$. Type III dolomite cements vary from high $FeCO_3$ cement to moderately high $FeCO_3$ cement. Type IV dolomite cements are low in $FeCO_3$. These differing compositions indicate variable fluid composition between dolomite cement types and within each dolomite cement type deposited.

CONCLUSIONS:

Differences observed between the four CL cements in this study and the cements of southeast Missouri indicate formation by fluids of differing compositions. Although the overall paragenetic sequence could not be determined, the partial paragenetic sequence of the cements observed indicates that type IIIa was deposited first, followed by type IIIb, type II, type IV and finally calcite cement. The overall paragenetic sequence could not be determined at this time. Further geochemical and petrographic studies are likely to provide the information necessary to understand the fluid flow history of the rifted area.

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